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(54) DYNAMO ELECTRIC MACHINES

(71) We, THE ENGLISH ELECTRIC COMPANY LIMITED, of 1, Stanhope Gate, London, W1A 1EH, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to dynamo electric machines of the kind comprising a stator having a core with a generally cylindrical bore, a stator winding incorporating a plurality of conductors supported around the bore of the stator core, and a generally cylindrical rotor mounted for rotation within the bore. Such machines will be referred to as being of "the kind specified".

With various types of dynamo electric machine it is advantageous to have the operative parts of the stator winding conductors, that is to say the parts extending longitudinally along the stator core between the end turns, disposed entirely in the air gap formed between the rotor and the stator instead of in slots in the stator core. This applies especially to large alternating current generators in which it would be particularly advantageous to position the operative parts of the stator winding conductors in the air gap.

However, the stator winding of such a machine is subjected to considerable mechanical force during normal operation and under fault conditions forces acting on the stator winding are greatly increased. The prime consideration in building a large alternating current generator with the operative parts of the stator winding conductors in the air gap is thus one of securing these parts of the conductors in the air gap so that they will resist mechanical forces tending to distort or destroy them.

According to the present invention in a dynamo electric machine of the kind specified having the operative parts of the stator winding conductors arranged in the rotor-stator air gap, said parts of the winding conductors are disposed in a plurality of axially extending trough members, each comprising a base with integral side walls extending substantially radially outwards, the outer ends of the side walls fitting into axially extending slots in the stator core, and the trough members, with the operative parts of the stator winding conductors accommodated therein, being arranged to form a substantially cylindrical structure within the stator bore.

Each trough member may include a radially outer cover plate fitted over the operative parts of the stator winding conductors, between said parts and the adjacent face of the stator core.

Each cover plate may include radially extending side walls which fit within the side walls of the trough member and within the slots in the stator core.

An axially extending cap of channel section may be fitted over the ends of adjacent radially extending side walls, and each cap may be a good fit within an associated slot in the stator core, or alternatively one or more of said caps may be of narrower width than the respective slots, in which case conformable packing is preferably located between the caps and the walls of the respective core slots.

In a modification of this last-mentioned arrangement having axial stator slots which are wider than the side walls, the caps may be omitted, conformable packing then being disposed directly between the sides of the or each slot and the portions of the side walls within the slots.

The width of the trough members may be such that they can be assembled to form a substantially unbroken continuous cylindrical structure within the stator bore.

Alternatively the trough members may be such that when they are assembled into the stator bore a space is left between at least one pair of side walls of adjacent troughs,

packing being inserted into each such space.

Preferably such packing comprises tapered wedges.

One or more of the axially extending slots in the stator core may be so shaped that at least part of the radially outer part of the slot is wider than the mouth of the slot, adjacent side walls extending into the slot being formed to extend circumferentially towards, or into, the wider part of the slot so that the side walls of the trough members can be keyed into the stator slots.

Preferably, pairs of adjacent side walls are of generally overall dovetail shape and fit into slots of a similar cross section.

The trough members an/or the cover plates thereof may be provided with radial and/or axially extending apertures, channels, or ducts for the passing of a cooling medium.

Alternatively the radially outer face of one or more of the cover plates may be formed with radially extending ribs so that when the cover plates are in position ducts are provided between at least part of these plates and the inner face of the stator bore for the passage of a cooling medium.

In another arrangement wedges or packing members used between trough members may be formed with ducts or channels for the passage of a cooling medium, or the wedges or packing members may be so arranged that such ducts or channels are left between wedges or packing members.

The trough members may be substantially all of the same width, although at least some of the trough members used to form the cylindrical structure may be of different widths from others of the trough members.

The trough members may be so arranged that the arcuate distance between the operative part of one stator winding conductor and another, or between groups of said parts differs around the circumference of the cylindrical structure whereby the complete stator winding can be arranged to give an armature reaction wave and generated e.m.f. of low harmonic contents.

The above described arrangement of the winding may be achieved by having trough members with walls of different thickness, or providing spacers between chosen pairs of adjacent trough members, or inserting wedges of different thicknesses between adjacent pairs of different trough members.

The stator winding end turns may be arranged in the known flared frusto-conical arrangement, and the stator core can comprise two semi-annular parts secured together after the respective parts of the stator winding have been secured in the two parts of the stator core.

In a modification of this arrangement the flared portions of the end turns are comparatively short and are at a relatively small angle to the axis of the stator bore, the end turns including straight portions extending from the ends of the flared portions parallel to the axis of the stator bore.

However the radially outer end turns may be arranged parallel or substantially parallel to the axis of the stator bore and the radially inner end turns extend inwardly towards the axis of the stator bore.

The stator winding end turn portions associated with the operative parts of the stator winding conductors in the trough members may be flared outwardly in known manner and the cylindrical structure built up of a number of trough members containing said operative parts of the winding conductors, the arrangement being such that one end of each trough member with the end turn portion can be passed through the stator bore.

The wedges or packing inserted into at least the lower part of the cylindrical winding structure may extend into the air gap to provide supporting surfaces for the rotor whilst the rotor is being inserted into the stator, those parts of the wedges or packing extending into the air gap being so constructed that they can be removed after insertion of the rotor into the stator bore.

In an alternative arrangement the wedges or packing between trough members may be such as to leave shallow axially extending slots in the face of the lower part of the cylindrical winding structure for receiving removable locating means on which the rotor can rest when it is being inserted into the stator.

A stator winding for a dynamo electric machine in accordance with the invention may be a single layer winding or a multiple layer winding.

A number of embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:—

Figure 1 shows one embodiment of the invention,

Figure 2 shows a modification of the Figure 1 embodiment,

Figure 3 shows a second embodiment or the invention,

Figure 4 shows a modification of the Figure 3 embodiment,

Figure 5 shows a third embodiment of the invention,

Figures 6 and 7 show modifications of the invention which can be used with the arrangements of Figures 1 to 5, and

Figure 8 shows one winding arrangement which can be used with the embodiment of Figures 1 to 7.

Figure 1 shows part of the stator core 10, part of the rotor core 11 and part of the rotor-stator air gap 9 between the stator and rotor cores of a dynamo electric ma-

chine. The operative parts of the stator winding of the machine are disposed in the rotor-stator air gap, being built up of insulated conductor bars two of which are shown in part at 12 and 13 and two in full at 14 and 15. The conductor bars have straight portions, which extend longitudinally along the stator core and provide the operative parts of the stator winding, these being the parts shown in Figure 1, and end turns (not shown). The stator winding conductor bars may be of known construction that is, comprising separate lightly electricallly insulated strands which are transposed, and some or all of the strands may be hollow for the passage of a cooling medium, the conductor bar being surrounded by more substantial insulation to withstand coil to coil voltages.

The straight portions of the conductor bars are accommodated in members in the form of troughs, parts of two of which are shown at 16 and 20. The trough 16 comprises a base having a pair of side walls formed integrally therewith, and is disposed with the side walls, one of which is shown at 17, extending radially outwards. The trough 16 is associated with a cover plate 18, also having radially extending side walls, one of which is shown at 19, the cover plate fitting within the trough as illustrated. The trough 20 similarly has a pair of radially extending side walls, one of which is shown at 21, and is fitted with an associated cover plate 22 with radially extending side walls as at 23. The ends of the four adjacent side walls 17, 19, 21 and 22 of the troughs 16, 20 are covered by a trough-like axially extending cap 24 which fits tightly into an axial slot 25 in the stator core 10.

Any suitable adhesive may be used between the troughs 16 and 20, cap 24 and the core 10, but as far as possible the use of adhesives is avoided so that the conductor bars can more easily be replaced.

All parts of the trough, cover and cap are of electrically insulating material and the width of each trough depends upon the winding design and the number of conductor bars to be accommodated in a single trough.

The side walls (not shown) at the opposite sides of the troughs 16, 20 may be the same as those illustrated or they could be of a different construction as, for example, described later in relation to other embodiments.

The embodiment of Figure 2 is similar to that of Figure 1 excepting that the slot 25 is larger than the cap 24, and packing 26, 27 and 28 is placed between the cap 24, and slot 25. The packing 26, 27 and 28 may comprise any suitable resin impregnated material, the resin being cured when the troughs have been assembled. Alternatively, the packing may comprise flexible bags into which a liquid resin material is pumped, the bags therefore being sealed and the resin cured.

This latter arrangement has the advantage of tightly positioning the troughs within the bore of the stator 10, also spaces 30 and 31 can be left between packing as shown, for the passage of a cooling medium such as a gas.

The arrangement of Figure 3 is similar to that of Figures 1 and 2 except that the side walls 17A, 19A, 21A and 23A are at a different angle to the respective parts 16, 18, 20 and 22 so that the side walls have a general overall dovetail outline which fits into a similarly shaped dovetail slot 25A. In this arrangement the troughs are secured within the stator bore by wedges which are tapered both radially and axially. The wedges are preferably inserted radially into the location space and tightened in position to secure the troughs and winding within the stator bore. Each wedge 33 or 34 will normally comprise a number of shorter wedge portions as shown in Figure 7. This Figure shows pairs of co-operating wedges 33 and 34 in position between trough members 16 and 20. The pairs of co-operating wedges are inserted radially and then driven towards one another. When the pairs of wedges have been fully tightened with one another dowel pins 44 are inserted to prevent axial movement of the wedges. It will be seen that the wedges are of such length that spaces 45 are left between wedges, these spaces can be used for the passage of a cooling medium.

Figure 4 shows an arrangement similar to that of Figure 3 but including packing 26A and 27A in the manner of the packing 26 and 27 of Figure 2.

The arrangement of Figure 5 is similar to that of Figure 1 except that the cap 24 is not used and packing 26B and 27B used, similar to the packing 26 and 27 of Figure 2.

Figure 6 is generally similar to Figure 3 but is a composite drawing which shows three modifications which may be applied to all embodiments. On the left hand side of Figure 6 the trough cover 18A is shown with projecting teeth so that spaces 41 are left between the trough cover and the face of the rotor bore. The spaces provide flow paths for a cooling medium, such as a gas, which is caused to flow through ducts or spaces in the stator core. The teeth 40 may extend only over part of the face of the trough cover depending upon the desired flow pattern of the cooling medium. Thus in places the thickness of the cover 18A could be increased to be equal to the thickness of the cover plus the thickness of the teeth 40 so as to provide greater strength and better electrical insulation.

The right hand side of Figure 6 shows ducts 41A in the face of the stator bore for the passage of a cooling medium and these ducts may extend along the whole length of the stator bore, or they may be provided only in parts of the stator core, for example, at the two ends thereof.

The wedges 33A and 34A of Figure 6 are shown with cutaway portions which provide a duct 42 for the passage of a cooling medium.

In some machines it is desired to cause a cooling medium flowing through the stator core to flow into the air gap of the machine. Such an arrangement could be provided for by forming radial ducts in the side walls of the troughs, and/or in the wedges where used, or even through the troughs and trough covers.

A further means of providing axial and/or radial ducts would be to use the spaces 50 (Figure 6) between conductor bars. In order to hold the conductor bars in place the spaces 50 must be filled with packing, but this could be or include packing provided with radial and/or axial ducts, or the packing could be corrugated to provide such ducts, in any arrangement the trough covers and troughs being provided with holes to align with ducts in the packing.

In the foregoing arrangements the trough covers 18 and 22 could be omitted if the electrical insulation of the conductor bars allowed, or the side walls of the trough covers could be omitted. The conductor bars shown in the drawings are of rectangular cross section but in that they are usually shaped in a mould they could be made arcuate so as to follow the contours of the troughs and covers. Alternatively some form of packing would be required between the flat surfaces of the conductor bars and the arcuate surfaces of the troughs and covers.

Further, the troughs described can conveniently be made of any suitable electrical insulating material used to make the best use of its mechanical strength in a given direction and mica-glass laminates are considered one of the more favourable materials for the manufacture of the troughs.

The stator winding of a dynamo electric machine comprises coils having two straight conductor bar portions which electrically lie approximately 180° apart and these conductor bar portions are joined by end turns. At one end the conductor bar portions are joined together and at the other ends, except the terminal ends, they are joined to the conductor bar portion of the next adjacent turn of a coil. In order to achieve this end turn arrangement the end turns are normally arranged in a frusto-conical arrangement which is flared outwardly at the ends of the stator core and since the end turns must pass over one another a single layer winding as described becomes a double layer arrangement at the end turns with an inner and outer cone of layers of end turns. With a double layer winding, which could be used with the present invention the end turns would be arranged in four concentric cones of layers of conductor bars.

With the flared out end turns it would not always be possible to construct a winding which could be threaded through the stator bore and one solution to this problem would be to build the whole stator, with respective parts of the winding, in two semi-annular parts which are later joined together.

However, if all conductor bars of a phase winding in one trough go into one layer and providing the trough does not contain too many conductor bars then it is possible to make a winding in which the straight conductor portions together with the end turn portions can be passed through the stator bore. One such winding layout is shown in Figure 8 in which the conventional R, Y and B references indicate the red, yellow and blue phases of a three-phase winding. It will be seen that this winding is a 1—5—1 interspersed winding, that is a total of seven coil sides per phase are arranged, one Y^1, five R, one B^1, one R, five B^1, one Y, one B^1 etc. This winding is arranged in troughs containing one, three, two and one straight conductors portions and the seven end turns 52 of each phase winding go into a single layer.

The most convenient winding to use from the manufacturing point of view may not be the best from the electrical aspect in that the harmonic content of the stator armature reaction wave and generated e.m.f. may be greater than desired. However, improvement can be obtained by adjusting the circumferential spacing of the conductor bars and thus the wedges of for example Figures 3, 4 and 6 can be chosen to be of a desired width to give a desired spacing. Alternatively spacers could be used between the trough side of the arrangements of Figures 1, 2 and 5. Since the sides of the troughs act as insulating barriers between the phase windings, the thickness can be chosen to give the desired degree of electrical isolation between phases.

In another end winding arrangement, where the air gap allows, the radially outer layer of end turns either extends straight out from the stator core, or else the end turns are bent so that they extend radially outwards from the stator bore at a small angle, the inner layer of end turns extending radially inwards. However, such arrangements would probably require longer end turns so as to clear the rotor with its end winding retaining rings and thus increase the length of the machine. A modification of the above described arrangement

is for the end turns to be formed with only short portions which extend radially and longer portions which then extend parallel to the axis of the stator bore. Such an arrangement can be used with end turns which extend radially outwards for a short distance and have further portions which extend parallel to the axis of the stator bore.

The wedges, or where used, spacers between troughs may be made to extend into the machine air gap in the lower part of the stator bore so as to provide a support surface for the rotor when it is inserted into the stator bore. However, it would be desirable to be able to remove the projecting portions so that they do not increase windage losses. An alternative arrangement would be to use spacers or wedges which left shallow ducts between trough sides, these shallow ducts acting to locate and hold in position means on which the rotor could rest, this means being later withdrawn axially from the air gap either whole or broken into pieces as it is withdrawn.

WHAT WE CLAIM IS:—

1. A dynamo electric machine of the kind specified having the operative parts of the stator winding conductors arranged in the rotor-stator air gap, wherein said parts of the winding conductors are disposed in a plurality of axially extending trough members, each comprising a base with integral side walls extending substantially radially outwards, the outer ends of the side walls fitting into axially extending slots in the stator core, and the trough members with the operative parts of the stator winding conductors accommodated therein, being arranged to form a substantially cylindrical structure within the stator bore.

2. A machine according to Claim 1 in which each trough member includes a radially outer cover plate fitted over the operative parts of the stator winding conductors, between said parts and the adjacent face of the stator core.

3. A machine according to Claim 2 in which each cover plate includes radially extending side walls which fit within the side walls of the trough member and extend into the slots in the stator core.

4. A machine according to Claim 3 including an axially extending cap of channel section fitted over the ends of adjacent radially extending side walls, each channel section being a good fit within an associated slot in the stator core.

5. A machine according to Claim 3 including an axially extending cap of channel section fitted over adjacent radially extending side walls for insertion into associated slots in the stator core with conformable packing between the channel sections and the walls of the core slots.

6. A machine according to any of the preceding claims wherein the width of the trough members is such that they can be assembled to form a substantially unbroken continuous cylindrical structure within the stator bore.

7. A machine according to any of the preceding claims in which the trough members are such that when they are assembled into the stator bore a space is left between at least one pair of side walls of adjacent members, packing being inserted into each such space.

8. A machine according to Claim 7 in which the packing comprises tapered wedges.

9. A machine according to any of the preceding claims in which one or more of the axially extending slots in the stator core are so shaped that at least part of the radially outer part of the slot is wider than the mouth of the slot, adjacent side walls extending into the slot being formed to extend circumferentially towards, or into, the wider part of the slot so that the side walls of the trough members can be keyed into the stator slots.

10. A machine according to Claim 9 in which pairs of adjacent side walls are of generally overall dovetail shape and fit into slots of a similar cross section.

11. A machine according to any preceding Claim 2 to 10 in which the trough members and/or the cover plates thereof are provided with radial and/or axially extending apertures, channels, or ducts for the passage of a cooling medium.

12. A machine according to any of Claims 2—5 in which the radially outer face of one or more of the cover plates is formed with radially extending ribs so that when the cover plates are in position ducts are provided between at least part of these plates and the inner face of the stator bore for the passage of a cooling medium.

13. A machine according to Claim 5, 7 or 8 in which wedges or packing members used between trough members are formed with ducts or channels for the passage of a cooling medium.

14. A machine according to Claim 13 in which the wedges or packing members are so arranged that such ducts or channels are left between wedges or packing members.

15. A machine according to any of the preceding claims in which the trough members are substantially all of the same width.

16. A machine according to any of Claims 1 to 14 in which at least some of the trough members used to form the cylindrical structure are of different widths from others of the members.

17. A machine according to any of the preceding claims in which trough members with the operative parts of the stator winding conductors therein are arranged in a

cylindrical structure in which the arcuate distance between the operative part of one stator winding conductor and another, or between groups of said parts differs around the circumference of the cylindrical structure whereby the complete stator winding can be arranged to give an armature reaction wave and generated e.m.f. of low harmonic contents.

18. A dynamo electric machine substantially as hereinbefore described with reference to and as illustrated in any one of Figures 1 to 8 of the accompanying drawings.

For the Applicants,
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Chartered Patent Agent.

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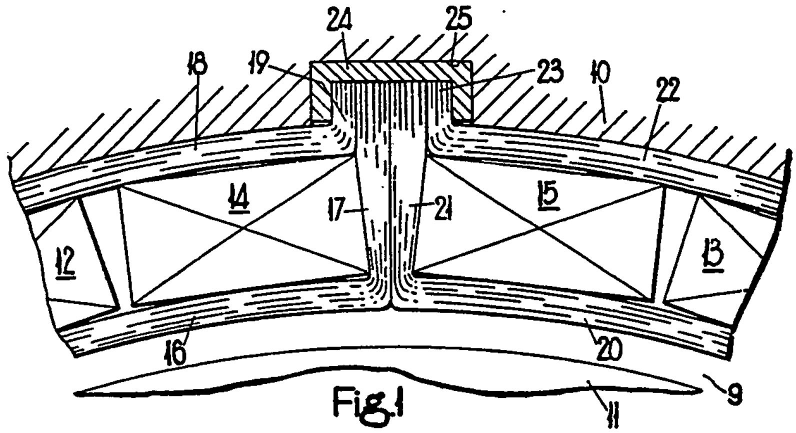

Fig.1

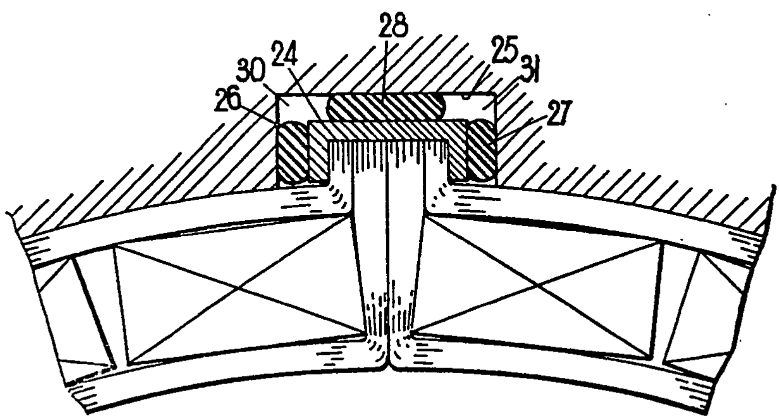

Fig.2

1365191 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

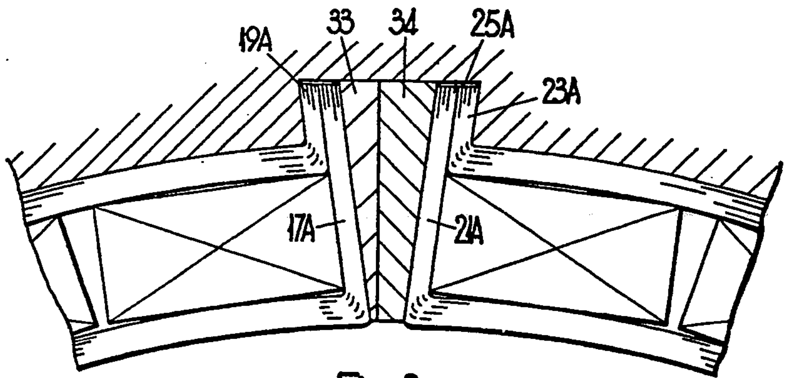

Fig.3

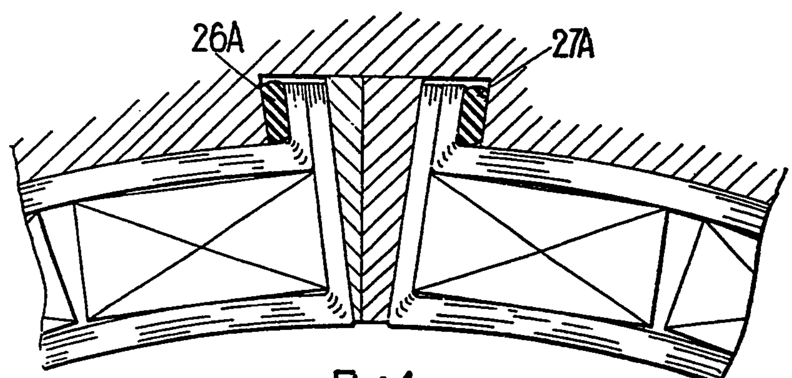

Fig.4

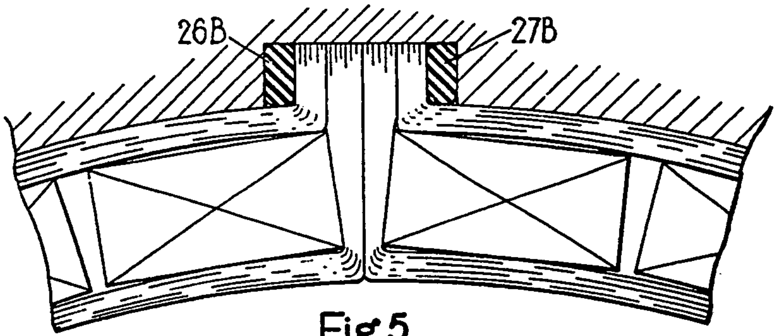

Fig.5

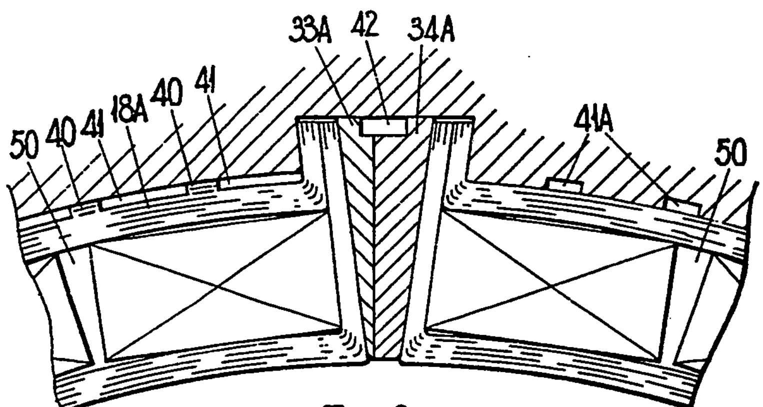

Fig.6

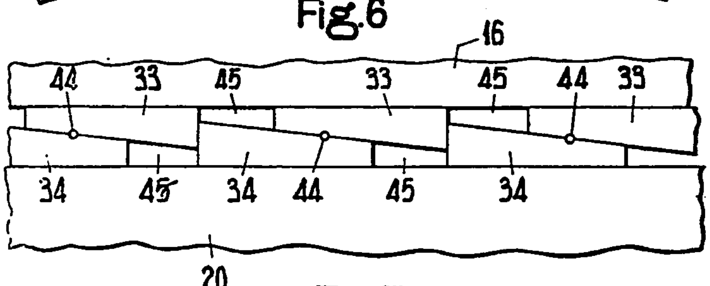

Fig.7

1365191 COMPLETE SPECIFICATION
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Sheet 4

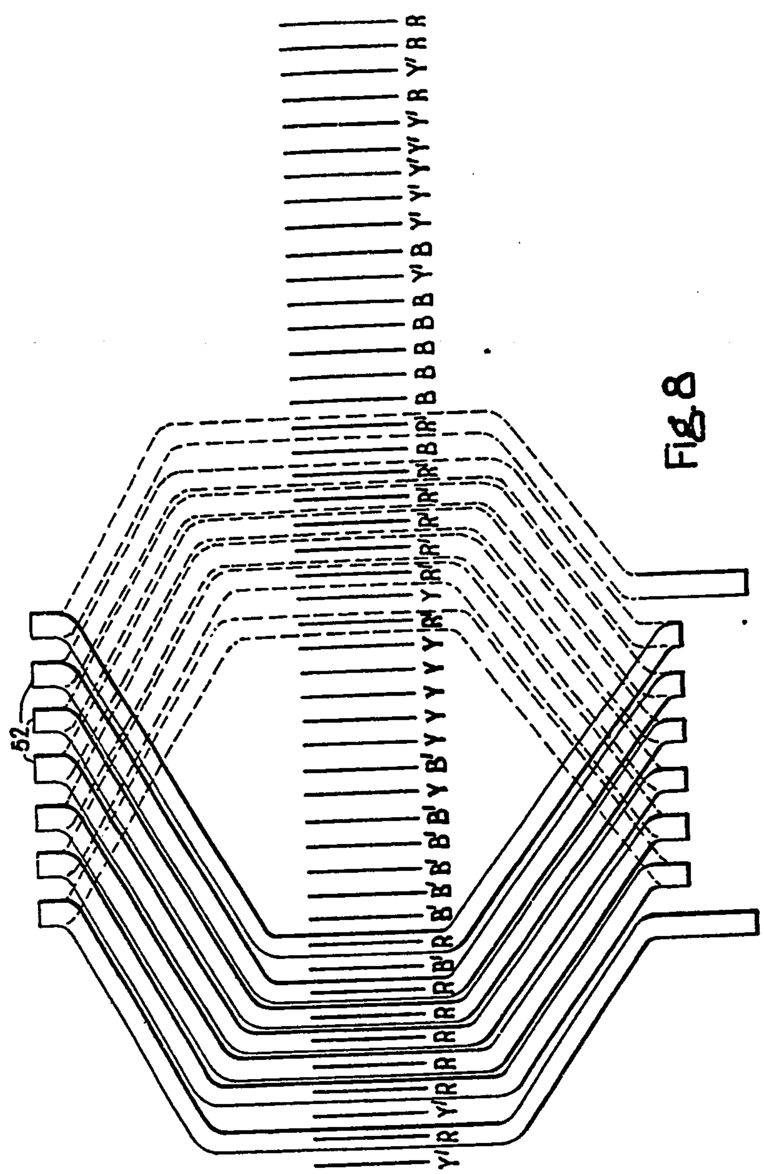

Fig. 8